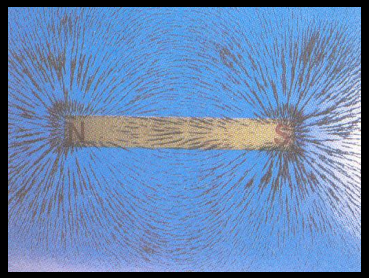


Magnetic Materials Laboratory

Center of Excellence in

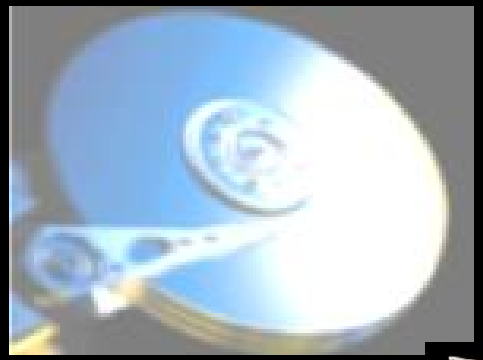
Magnetic Sensor and Actuator Materials

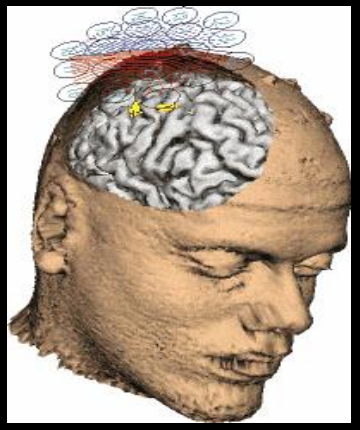
Prof. Siva Guruswamy

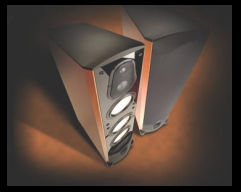
Prof. Michael K. McCarter

Department of Metallurgical Engineering
University of Utah

Off-Site Review, May 10, 2005

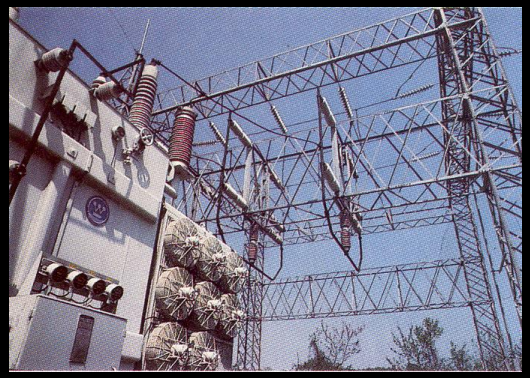


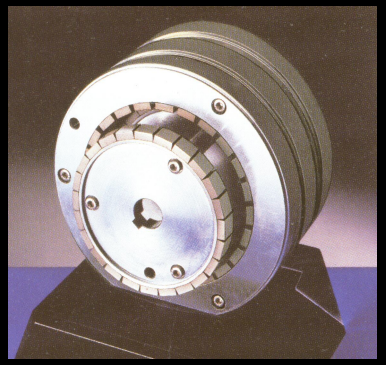


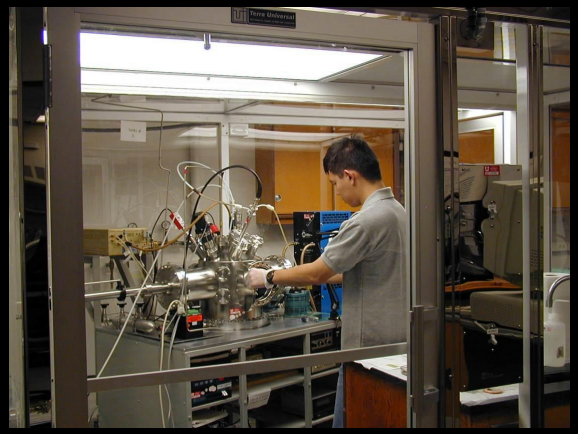


Magnetism is all around us, and the magnetic materials and devices impact most facets of our daily life.

Market value > $ 100 Billion



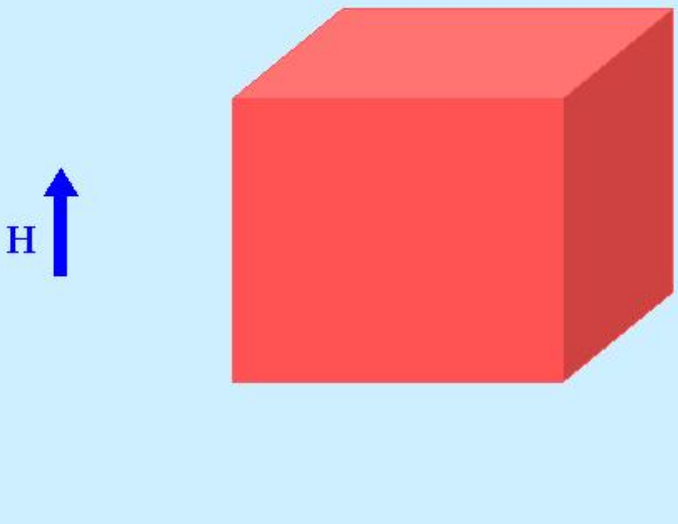




- **Established in 1991, MML is a state of the art magnetics laboratory**
- **Engaged in developing various magnetic technologies that include**
  - **Magnetostrictive Materials and devices**
  - **Magnetic Storage Media**
  - **$Nd_2Fe_{14}B$ based High Energy Density Permanent Magnets**
  - **Magneto-resistive devices**
  - **Novel processing approaches**
  - **Advanced materials characterization**

Technology

Discovery of Large Low-Field Magnetostriction in Rare-Earth Free and Ductile FeGa Alloys at MML

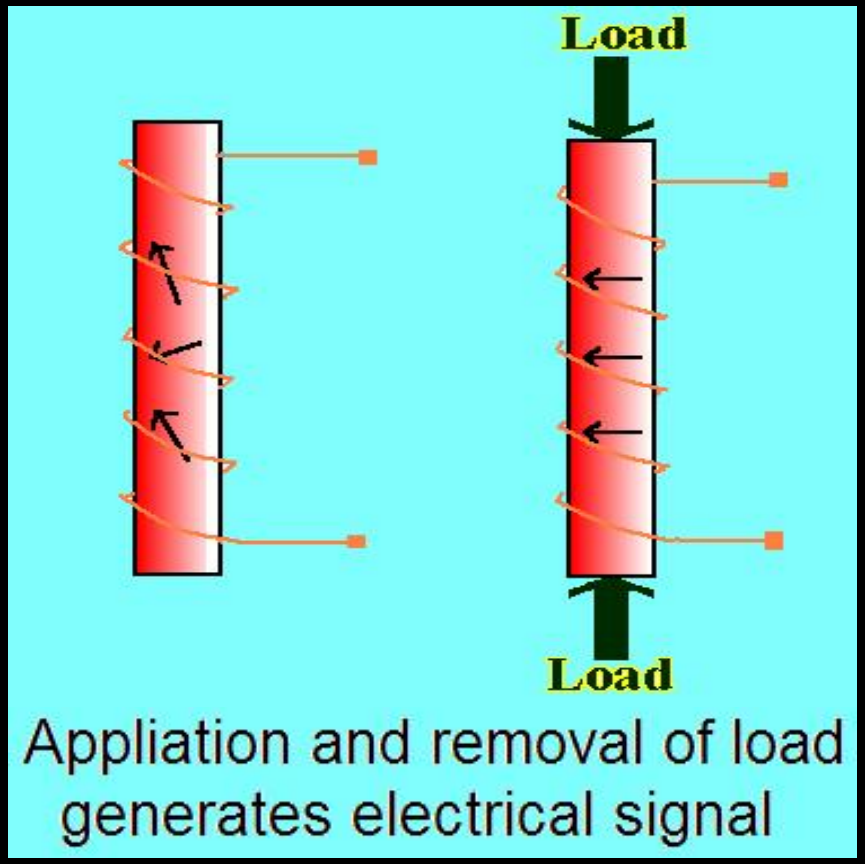


Change in applied magnetic field causes changes in length

- Magnetostriction of Fe increased by 10 times.
- Magnetic fields <100 Oe needed
- Very low hysteresis
- Excellent mechanical properties
- High temperature operation
- No refrigeration/cooling system
- Minimal design restrictions

Actuation Function

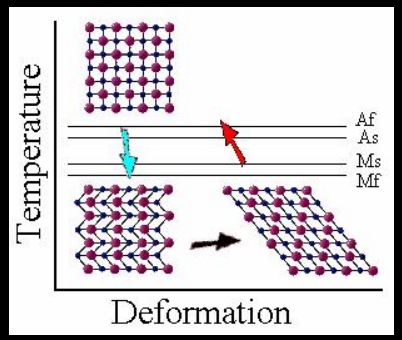
Joint patent application with Navy

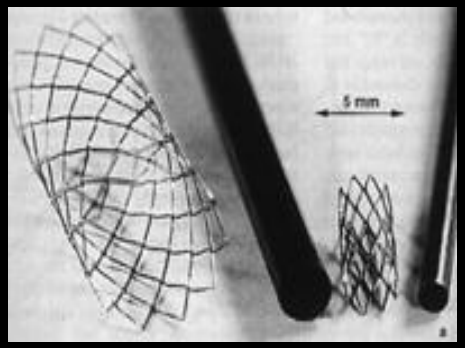


Sensing Function

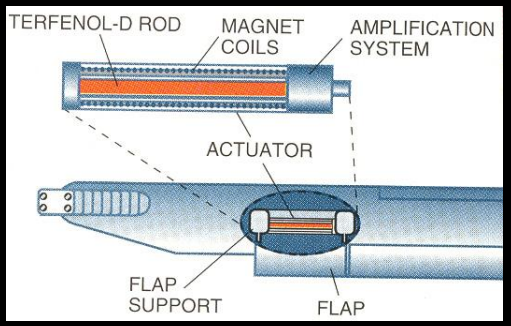
Classes of Smart Materials

Shape-memory alloys

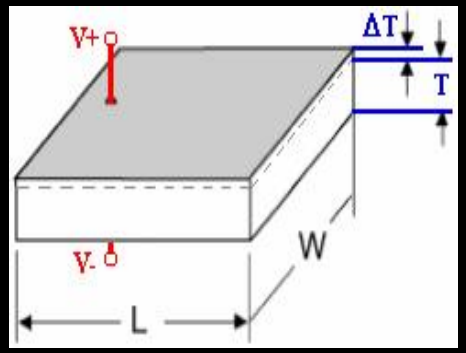




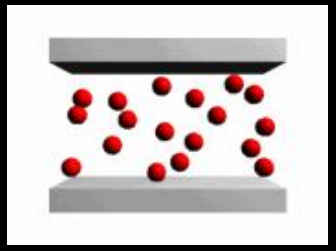
Magnetostrictive Alloys

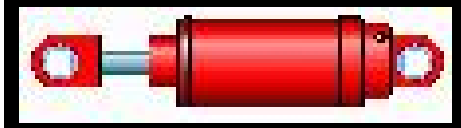


Piezoelectric alloys



Electrorheological & Magnetorheological Fluids



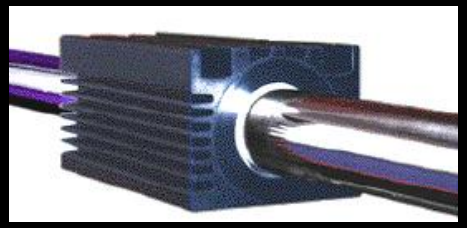


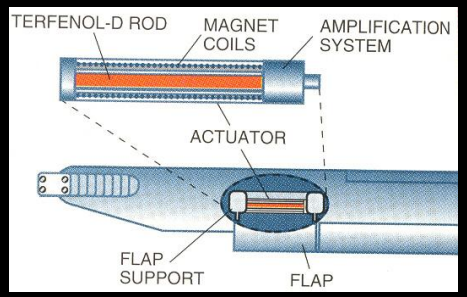
Magnetostrictive Materials

- Belong to the class of Smart Materials
- Analogous to piezoelectric materials but
  - Do not require electrical contact
  - Large frequency bandwidth
  - Large displacement per single element
- Rugged
- High stiffness and large delivered force (50 MPa)
- High energy density (14-25 kJ/m^3)

Applications in Sensing and Actuation

Linear motor/Actuator

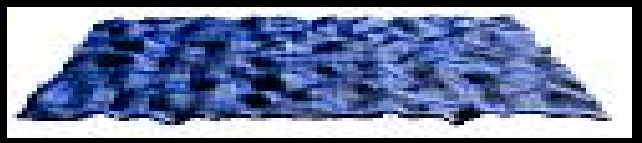




Active Vibration Damping Devices

Acoustic Sensor

Speaker



Nano-Positioning Devices

Uniqueness compared to currently widely used sensor and actuator alloy

Material	Saturation Strain ($*10^{-6}$)	Curie Temperature	Operating Temperature Range	Coercivity (Oe)	Saturation Field (Oe)
Terfenol-D	**1200 (Typical)**	**376 °C**	**-50 - +72 °C**	**~35**	1000-2000
FeGa	**200-400 (Typical)** (>400 ppm feasible)	**650-780 °C**	**Very Broad Range** (Cryogenic to >>150 °C)	**<5**	<100

Mechanical Properties

Material	Tensile strength (MPa)	Ductility	Young 's modulus (GPa)	Cost
Terfenol-D	28-56	0%/Brittle	**~30**	Expensive
FeGa	>500	Up to 25%/ Ductile	**110-170**	Cheaper

FeGa alloys will replace widely used Terfenol-D in many applications

Center has a core technology that has a broad application and product range

Phase 1:

Products with a rapid product development and marketing cycle (2 Years)

Ultrasonic cleaners and sonic devices

Linear motors and Precision positioning systems,

ABS modules and micro-valves

Phase 2

Products with a long product development and marketing cycle 3-5 Years

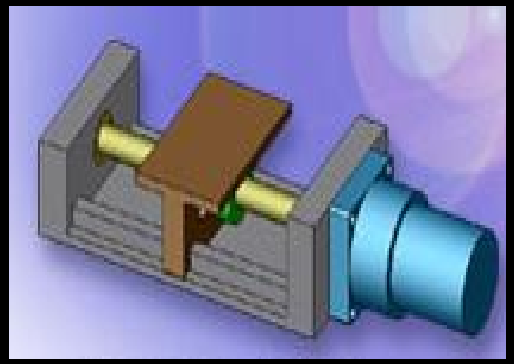
Torque sensors for mining applications

Position and level sensors and other products.

Industrial Ultrasonic Cleaners & Sonic Devices

Can operate over a broad frequency range that cover the sonic and ultrasonic range.

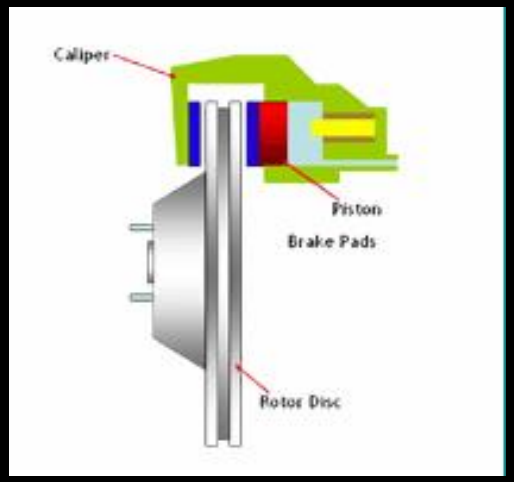
Nano-Positioning and Linear motors



Controlled movements in the Angstrom and nm level.

Used in nano- and micro-level machining and measurements

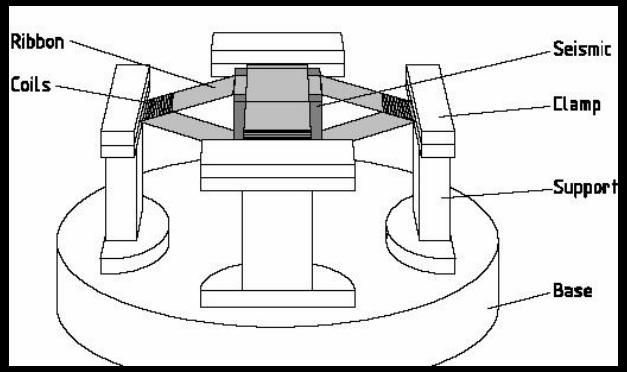
Anti-lock Breaking System Modules



Position and Level Sensors

Micro-valves

Accelerometers



Torque Sensors

U.S. ULTRASONIC MARKET TO GROW TO $ 5.35 BILLION BY 2008

	$ Millions	
	2005	**2008**
High Power Ultrasonics	845	1,055
Total all Ultrasonics	4,190	5,353

INDUSTRIAL SENSOR MARKET TO CROSS $ 6.7 BILLION BY 2006

* BRCResearch

Center Revenue Projections

	($ Millions)				
	2005	**2007**	**2008**	**2009**	**2010**
Market share in High Power Ultrasonic and other devices (Goal)	-	-	13 (~1%)	126 (~12 %)	175 (~17%)
Total Sales	-	-	13	126	175
Revenues	0.5*	2.5*	13.1 M	126.1	175.1
Expenses	0.5	2.5	12.5 M	119.8	164.2
Net Income	0	0	0.5 M	6.3	8.9

* Investments/grants for product development and marketing

Technology Rights

- Pending Fundamental Patent Application on FeGa alloys
- 3 Invention disclosures, 2 Provisional Patent applications being filed

Other Patents

- 1 Patent on Terfenol-D composite
- 2 Patents on coating for blood contacting devices

TEAM

- Dr. Siva Guruswamy, Professor, Metallurgical Eng., and Director of MML, U of U

  Magnetic Material Processing, Device Design and Development, Facility development, Marketing, Direct Center Activities

- Dr. Michael K. McCarter, Prof. & Chair, Mining Eng., U of U

  Product Performance Testing and design input, Material Processing

- Dr. Rajiv Kulkarni/ Zach Miles Esq., Technology Transfer Office, – IP protection/Marketing
- Marketing Consultant
- Graduate students

Financial and In-kind Support

National Science Foundation (Current)

University of Utah (Current)

State of Utah Mineral Leasing Grants (Past)

PI Donations (Current)

Office of Naval Research Travel Grant (Past)

Partners/Supporters

- ENECO,Inc, Salt Lake City
- Ceramatec, Inc, Salt Lake City
- MMC Technolgies, Division of Maxtor, San Jose, CA
- TerraTek, Salt Lake City
- US Magnesium LLC, Salt Lake City,
- BARD Access Systems, Salt Lake City,
- Others (…)

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